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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 571

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER December 15, 1917

IMP. BUR.
25 FEB. 1918
ENTOM.

THE PECAN LEAF CASE-BEARER.[1]

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INTRODUCTION.

Because of the increasing importance of the pecan industry the Bureau of Entomology in 1913 established a field station at Monticello, Fla., for the purpose of studying pecan insects under the most advantageous conditions. The writer was placed in charge of the investigations, under the direction of Dr. A. L. Quaintance. In the spring of 1914 Mr. A. I. Fabis was detailed to assist in the work of this station. Extensive investigations, covering a period of nearly four years, have shown the value of certain repressive measures for the control of some of the more injurious pecan insects and have resulted in the compilation of considerable data on their life histories and natural enemies. One of the principal insect pests with which the pecan grower has to contend is the pecan leaf case-bearer (*Acrobasis nebulella* Riley). The present publication is intended to give the information now available concerning the life history and control of this insect.

The writer wishes to thank the various pecan growers who have rendered assistance in this work.

[1] *Acrobasis nebulella* Riley; order Lepidoptera, family Pyralidae.

HISTORY.

The pecan leaf case-bearer (*Acrobasis nebulella*) was first described by Riley in 1872 (1),[1] under the name *Phycita* (*Acrobasis*) *nebulo* Walsh var. *nebulella*, from a single specimen reared from wild crab (*Crataegus* sp.). In 1887 Ragonot (2) described this insect as a "new species," naming it *Acrobasis palliolella*, and in the following year Hulst (3) also described it as "new to science," under the name *Acrobasis albocapitella*. In 1890, in Hulst's article on "The Phycitidae of North America" (4), *albocapitella* Hulst is listed as a synonym of *palliolella* Rag., and Riley's original description of this insect is given under the name *Mineola indiginella* Zell., var. *nebulella*. Ragonot (5), in 1893, in his "Monographie des Phycitinae et des Galleriinae," treated Riley's *nebulella* as a variety of *Acrobasis indiginella* Zell., and *Acrobasis palliolella* as a distinct species, giving *albocapitella* Hulst as a synonym. The same classification is given in Dyar's "List of North American Lepidoptera" (7), except that the species *indiginella* is placed in the genus *Mineola*. In Florida, in 1901, Gossard, then State entomologist (6), mentioned injury to pecans by *Mineola juglandis* and *Acrobasis caryae*, but the writer is of the opinion that some of this injury, if not all, should have been attributed to the pecan leaf case-bearer (*Acrobasis nebulella* Riley). In 1902 Gossard (8) again made brief mention of what was undoubtedly this species under the name "pecan bud-worm." Fiske (9), in 1902, under the caption "Notes on certain injurious insects in Georgia," gave life-history notes and suggested remedies for the pecan leaf-crumpler, which was presumably the insect discussed in this publication. The following year (1903) Chittenden (10) reported damage to pecan buds in Georgia by this species, and Herrick (11), in 1904, referring to Chittenden's report of injury in Georgia during 1902, gave notes on *Acrobasis* sp. It would appear that the life-history notes given in Herrick's article pertain to the pecan bud-moth (*Proteopteryx bolliana* Sling.) and not to the pecan leaf case-bearer. In 1905 Gossard (12), still the Florida State entomologist, gave an extended account of this insect, but unfortunately confused some of his notes and photographs on this species with those of the pecan bud-moth. In 1909 Herrick (14) published a bulletin on this species, giving remedies and incomplete life-history notes, as based on its occurrence in Texas. During the same year (1909) Dyar (13), under the caption "Notes on the species of Acrobasis, with descriptions of new ones," gave notes on both *A. palliolella* Rag. and *A. nebulella* Riley, stating that he "expects it will be found that *palliolella* is not more than a variety of *nebulella* Riley."

Worsham (15), in 1910, made a brief mention of this species as an important pest of pecan in Georgia, and in the following year (1911)

[1] Reference is made by number to "Literature cited," p. 27.

Chittenden (16) included it in his paper entitled "Insect enemies of the pecan." Gossard (17), in 1913, under the caption "Various insects affecting nut trees," gave a short account of this species and stated that errors crept into his publication (12) on insects of the pecan, with regard to the pecan case-bearer and the pecan bud-moth. The life history and habits of the pecan leaf case-bearer were given by the writer in a paper read during the meeting of the Florida State Horticultural Society in 1914.

The foregoing paragraphs include the more important references to this species in so far as the writer has been able to determine them.

SYNONYMY.

Dr. Dyar's position on the synonymy of certain species of Acrobasis is defined in the following advice under date of August 4, 1914, given in answer to an inquiry of the writer:

Palliolella is the male, *nebulella* the female of one species I believe. The males are generally whiter over thorax and base of wings. *Nebulella* (1872)=*palliolella* (1887).

The synonomy of *Acrobasis nebulella* Riley is as follows:

Phycita (*Acrobasis*) *nebulo* Walsh var. *nebulella* Riley, Fourth Ann. Rept. Ins. Mo., 1872, p. 41.
Acrobasis palliolella Ragonot, Diag. N. A. Phyc., 1887, p. 4.
Acrobasis albocapitella Hulst, Ent. Am., 1888, p. 116.

It seems advisable to note that in 1909 Dyar (13) made the following statement concerning *Acrobasis nebulella* Riley:

This name is listed as a variety of *Mineola indiginella* Zeller, but Riley's type before me is clearly an *Acrobasis* and differs from *palliolella* only in the gray color of thorax and base of forewings. *Minimella* Rag., made to replace Hulst's *nigrosignella* by Ragonot and referred to the synonymy of *caryae* Grote by Hulst, will find place here as a synonym.

DISTRIBUTION.

The pecan leaf case-bearer is a native insect and is distributed more or less over the same territory as is its preferred hosts, the various hickories. The following records show that it is quite widely distributed throughout the United States. The distribution for *Acrobasis nebulella* Riley and *Acrobasis palliolella* Rag., along with certain notes as given by Dyar (13), is as follows:

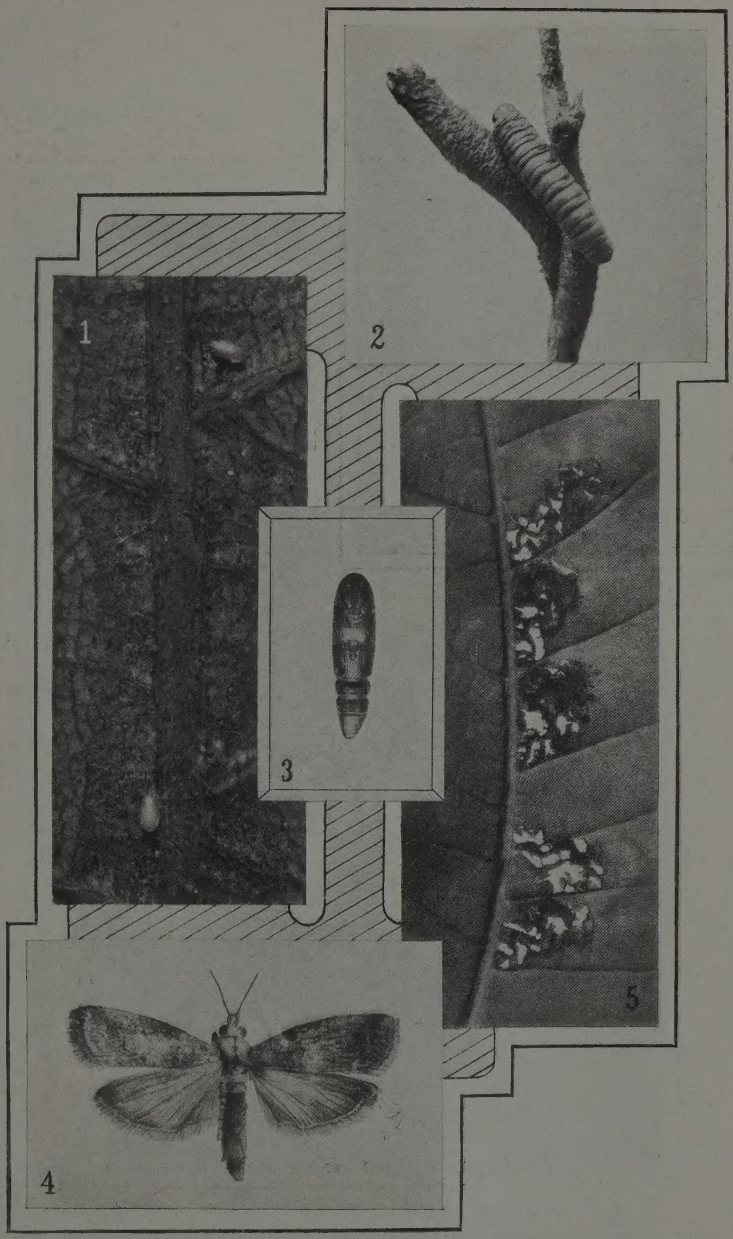
Palatka, Fla., on pecan, issued May 27, 1903; Olustee, Fla., June, 1904; Black Jack Springs, Tex. (through Dr. Wm. Barnes); Cairo, Ga., issued June 7, 1903; Blackshear, Ga., on pecan, issued May 28, 1902 (W. R. Williams); Washington, D. C., on walnut, issued June 7, 1903 (August Busck); Chicago, Ill., July 1900 (Coll. W. B. Kearfott); Atlanta, Ga. (W. M. Scott); Kerrville, Tex., at light, May 30 to June 1, 1906 (F. C. Pratt); Blackshear, Ga., on pecan, issued June 12, 1902 (Dept. Agr. No. 8637); Rhinebeck, N. Y., July 27, 1888 (H. C. Dyar), the last a female and the reference, therefore, less certain.

H. M. Russell reported this species as reared from pecan on May 18 and 20, 1908, at Orlando, Fla. (Chittenden No. 348), and D. K. McMillan, at one time connected with the bureau, recorded it on May 25, 1908, from pecan at Brownsville, Tex. (Chittenden No. 1045). The material on which Riley based his description was probably collected in Missouri, and the material on which Hulst (3) described this insect under the name *Acrobasis albocapitella* was taken in Canada (Ontario). Fiske (9) reported it from Georgia, Gossard (12) from Florida, and Herrick (14) from Texas (Cuero and College Station). The writer has seen it occurring in injurious numbers on pecan in Florida, Georgia, Alabama, Mississippi, Louisiana, and Texas. It has been reported to be injurious in South Carolina, and it is also known to occur in North Carolina and Virginia, but in these States apparently it does only minor damage. So far as is known, this insect ranks as a serious pest only in the southern part of the pecan-growing area, but from the foregoing records it can be seen that the species is quite widely distributed over this country.

FOOD PLANTS.

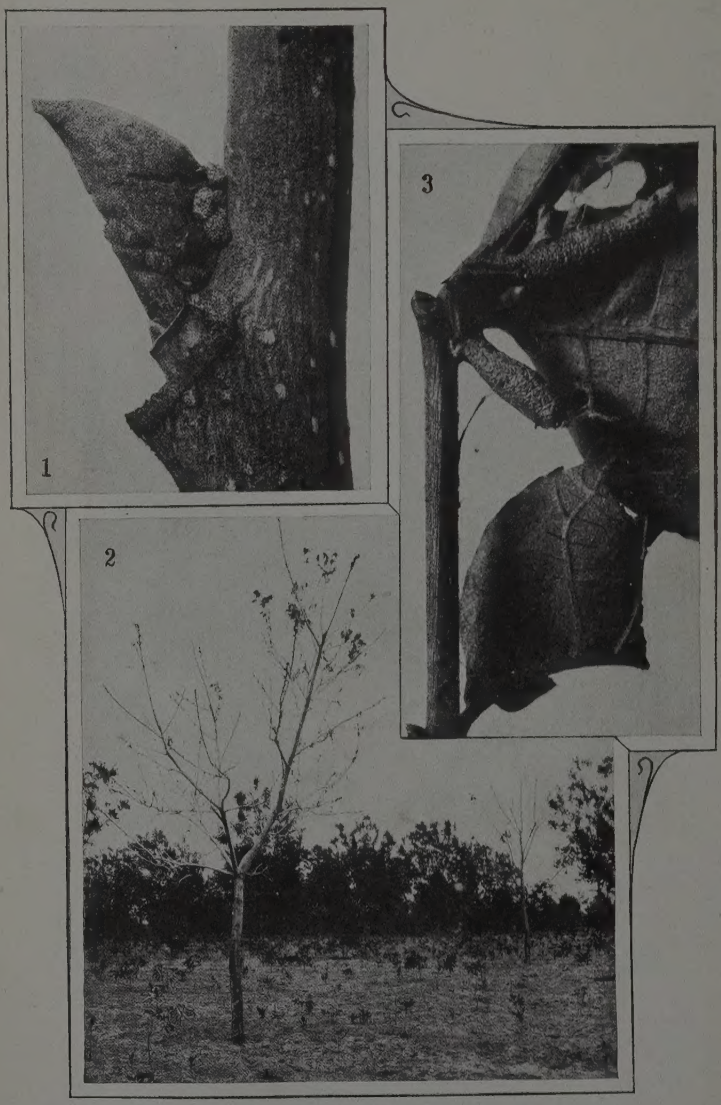
In his original description, Riley (1) gave wild crab (*Crataegus* sp.) as the food plant from which a single specimen was reared. Dr. Dyar (13) made the following statement: "I have 23 specimens before me, 4 bred by Dr. Riley on hickory and walnut, including the type of *nebulella*," and he also gave numerous records of its occurrence on pecan. Dr. Dyar (13) also gave a record made by Mr. August Busck in which this insect was reared from walnut on June 7, 1913, at Washington, D. C., and Mr. M. M. High (14) found it on wild hickory near College Station, Tex. Gossard (12) reared it in abundance from the pecan in Florida, and Herrick (14) states that he "reared many specimens from pecan at Cuero, Tex., where it was very abundant and doing serious damage." There are also many other records of this species occurring on pecan. So far as the writer's experience goes, the larvæ have been observed feeding upon hickory, Japanese walnut, and pecan, and moths have been reared from material collected on pecan and hickory. The writer has not yet found the black walnut to be attacked, although not infrequently that species has been found growing in close proximity to badly infested pecan trees. According to the writer's observation and experience it is very difficult to find larvæ on various species of Hicoria other than *H. pecan*, even in sections where this species ranks as a pest in pecan orchards. This species shows a decided preference for the pecan, and in many sections of the South it is the most injurious insect affecting the culture of this nut.

In making observations in pecan orchards in localities where this insect occurred in injurious numbers, an apparent varietal resistance



STAGES AND WORK OF THE PECAN LEAF CASE-BEARER (ACROBASIS NEBULELLA).

FIG. 1.—Eggs. FIG. 2.—Larva and case. FIG. 3.—Pupa. FIG 4.—Adult, or moth. FIG. 5.—Larval cases on pecan leaflet during the summer. All enlarged. (Original.)



WORK OF THE PECAN LEAF CASE-BEARER (ACROBASIS NEBULELLA)

FIG. 1.—Hibernacula, or winter cases, around pecan bud. FIG. 2.—Pecan trees defoliated by larvæ in the spring. FIG. 3.—Completed larval cases where pupation takes place. Figs. 1 and 3, enlarged; fig. 2, reduced. (Original.)

WORK OF THE PECAN LEAF CASE-BEARER (ACROBASIS NEBULELLA).

FIG. 1.—Pecan buds injured by larvæ in the spring. FIG. 2.—Larval cases on compound pecan leaf during the summer. FIG. 3.—Work of nearly matured larvæ on pecan foliage. FIG. 4.—Work of larvæ on pecan foliage at blossoming time. All slightly reduced. (Original.)

to its attacks was noticed. Such varieties as the Frotscher, Van Deman, Nelson, Pabst, Schley, Delmas, Stuart, and Success were badly infested, while the Mobile, Georgia, Havens, Teche, Waukeenah, Moore, Moneymaker, and Curtis were slightly infested. No reason can be given for this apparent varietal resistance, but it may be stated in general terms that pecan trees with very small leaves seem less likely to be heavily infested by this insect. Unfortunately, many of the best commercial varieties of pecan are subject to attacks by this pest.

CHARACTER OF INJURY.

The most serious damage to pecan occurs during the early spring. The larvæ feed voraciously upon the unfolding buds and leaves, as is shown in Plate III, figure 1. Just as the buds are bursting, the little overwintering "worms" gnaw their way out of their hibernacula (winter cases), which invariably are to be found snugly packed around the buds. Usually they migrate immediately to the tips of the swelling buds, upon which they partake greedily of their first meal. Upon leaving hibernation quarters some larvæ have been observed eating directly through the side of the buds, instead of entering at the tip as is usually the case. As these larvæ begin to work very early in the spring it takes but little feeding to inflict serious injury. On badly infested trees it is not uncommon to see from three to five larvæ, and sometimes more, entering a single bud. Under these conditions there is little chance for even partial development of the foliage. As the larvæ when in sufficient numbers are capable of eating the green foliage as rapidly as it appears, it is not unusual for the trees to remain defoliated for a considerable length of time. The writer has seen pecan trees kept in this condition for several weeks solely because of the attacks of this pest. On such trees the buds turn brown as a result of the feeding of the larvæ, and a block of badly infested trees takes on the appearance of blight by fire. (Pl. II, fig. 2.) When the infestation is less severe the larvæ web and tie the tender leaves together into masses, which soon become unsightly due to the wilting of the leaves and the presence of particles of excrement and larval cases with which they are united. (Pl. III, figs. 3, 4.) Late in the spring, when about half grown, the larvæ attach their cases to the leaf petioles, draw the leaflets together, and feed freely. (Pl. II, fig. 3.)

After having kept the trees in a defoliated condition for some time and, therefore, when pressed for food, these insects occasionally attack both blossom and leaf buds by burrowing directly into the ends. When thus deprived of their foliage the trees are fairly certain to become so devitalized as to be unable to make proper growth during the remainder of the season or to form fruit buds for the following season. Indirectly the trees suffer by becoming much

more susceptible to attack by certain wood-boring insects and less able to withstand drought in summer.

During the summer and early fall the larvæ, then very small and feeding but little, will be found attached to the underside of the leaflets in brownish, minute, tortuous, and winding cases (Pl. I, fig. 5; Pl. III, fig. 2), which greatly resemble at a glance brown spots such as might be caused by certain fungi. These tiny cases are enlarged only as it becomes necessary for the larvæ to build their way to new feeding areas. A detailed description of the larval cases as they appear during the summer and fall months is given on page 7. So far as the writer has observed, the injury caused to the foliage during the fall is so slight that the leaves do not fall prematurely.

DESCRIPTION.

THE EGG.

The egg is elliptical in outline, somewhat convex above and flattened below. Viewed with the hand lens the surface is quite smooth, but under higher magnification it is very faintly punctate. When first deposited the egg is white with a slight greenish tinge, translucent, and iridescent in some lights. The empty shell is white. The average size of five eggs was found to be 0.55 by 0.33 mm. (0.0216 by 0.0129 inch). The eggs are deposited singly on the underside of the leaflet and usually at the junction of the veins with the midrib. Moths confined in rearing cages (battery jars) have been noticed sometimes ovipositing upon the upper surface of the leaves, but in no case has the writer observed such oviposition under natural conditions. (Pl. I, fig. 1.)

THE LARVA.

Upon hatching the larva is a little less than a millimeter (0.039 inch) in length. The head and prothoracic shield are brown in color, while the rest of the body is of a much lighter shade of brown. When extended the full-grown larva averages about 14.5 mm. (0.5708 inch) in length by 2.0 mm. (0.0787 inch) in greatest width. The head is round, shiny dark brown or blackish in color, and slightly rugose. The general color of the body is very dark green, except the prothoracic shield, which is somewhat lighter. The shape of the larva is nearly cylindrical, tapering slightly at both ends, but more posteriorly than anteriorly. The body is sparsely covered with fine long hairs and on either side of the dorsal surface of the second thoracic segment is a small well-defined tubercle, from the black center of which arises a fine hair. The skin, especially in the thoracic region, is quite wrinkled, there being a pair of crescentic folds on the dorsum of the second and third segments. Rudiments of these folds are evident on the other segments, but they are not prominent. The first four pairs of prolegs are quite short, only

about one-half the length of the anal pair. The pedal end of each proleg is armed with two concentric ridges of minute claws or hooks. The thoracic legs are brownish, with a tinge of olive green, and each terminates in a single claw. (Pl. I, fig. 2.)

THE LARVAL CASES.

When first hatched the larva begins to feed upon the leaf surface about the egg. Soon after it constructs a brownish case out of excrementitious grains and a lining of grayish-white silken threads. The base of the summer case, as is shown in Plate I, figure 5, is invariably placed near the midrib. The case is enlarged by building away from the midrib in whatever direction the larva may chance to feed, and as the larva extends its feeding pasture in one direction and then in another the case soon assumes a very tortuous course. Throughout its entire length the case is securely attached to the under surface of the leaflet. It is composed of a rather flimsy texture of silken threads and pieces of excrement or frass, with the larger end open, and under this protection the larva extends its feeding area unnoticed. While the larva confines its attacks to the underside of the leaf, the upper surface becomes deadened and presents a brown patch, which becomes disintegrated, due to the effects of the weather. (Pl. III, fig. 2.)

In the autumn, before the foliage begins to drop, the larvæ migrate to the buds, where they construct very small, oval, brown cases (hibernacula), measuring about 1 mm. (0.039 inch) in diameter, in which they pass the winter. (Pl. II, fig. 1.) These brown cases are lined smoothly with whitish silken threads, and are covered with excrementitious particles and bits of bark and bud scales which render them rather difficult of detection upon superficial examination.

The cases of the matured larvæ as they appear in the spring are made of particles of frass, or grains of excrement, which are very closely woven together by means of fine silken threads, and are lined inside with a smooth surface of grayish-white silk. (Pl. II, fig. 2.) The finished case averages about 18 mm. (0.70 inch) in length, and is slightly enlarged in the middle. It is always attached to the petiole of the leaf by means of a foot stalk of grayish-white silk. The larva, as a rule, draws down and fastens two or more leaflets about its case, usually feeding upon the tips of these leaflets from this shelter. At first the case is rather loosely woven and slightly curved, but before the larva reaches maturity the case becomes straight with the unattached end larger than the attached one. The completed case, which is of a brownish-gray color, is so compactly constructed and tough that it can be torn only with great difficulty. Just before the larva pupates it seals the distal end of the case with a rather flimsy layer of silk.

THE PUPA.

The pupa (Pl. I, fig. 3) is of the usual form and without conspicuous markings. When first formed it is of a dark-brown color, with a tinge of olive green, but with age it changes to deep shiny mahogany brown. The dorsal surface of the abdomen is finely punctate. The average size of five individuals was found to be 8.1 mm. (0.318 inch) by 2.26 mm. (0.088 inch). The pupa is formed within the case, and the pupal skin is not extended upon emergence of the moth.

THE ADULT OR MOTH.

The pecan leaf case-bearer was first characterized and named in 1872 by Riley (1) as *Phycita* (*Acrobasis*) *nebulo* Walsh variety *nebulella*. The original description is as follows:

> I have bred a single specimen from wild crab (*Crataegus*) which differs in some essential features from the normal form, but which nevertheless can only be considered a variety of it, as I observed no larval differences. It differs in the more uniform and subdued tone of the front wings, the markings being more suffused and indistinct; but principally in the relative narrowness of the space outside the transverse posterior line, the greater consequent width of the middle area, and smallness of the triangular brown spot—the space it occupies on the inner margin being scarcely one-half as wide as that between it and the transverse posterior line. The discal spots are also separated. Described from one good specimen.

A less technical description of the moth is as follows:

> The moths measure from 14 to 18 mm. (0.55 to 0.70 inch) across the expanded wings, and they present a wide variation in color. The head, palpi, thorax, base of forewings and legs are distinctly snow-white in the specimens of males, while in the females these parts are more or less dusky gray. The abdomen is more or less white, washed with fuscous. The outer two-thirds of the forewings are gray with blackish patches, or spots, which vary to some extent. The discal spots are invariably separate and distinct. Not far from the base of the forewings is a reddish-brown stain, which is very faintly evident in some of the lighter colored forms. The hind wings are ashen gray and darker toward the outer margin. (Pl. I, fig. 4.)

SEASONAL HISTORY AND HABITS.

The seasonal-history records were obtained at Monticello, Fla., during 1913, 1914, and 1915 in an open-air insectary, in which glass jars were used as rearing cages. In all rearing work pertaining to life-history studies pecan foliage was employed.

THE ADULT AND EGG STAGES.

The time of emergence.—From material under observation during the season of 1913 it was determined that moths emerged from May 9 to July 12, inclusive. The cages, upon which the general emergence records are based, were examined daily. The dates of issuance of 269 individuals are shown in the following table:

TABLE I.—*Time of emergence of moths of the pecan leaf case-bearer during 1913 at Monticello, Fla.*

Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.
	1913.		1913.		1913.		1913.
1	May 9	3	May 30	4	June 14	7	June 29
1	May 11	3	May 31	7	June 15	8	June 30
1	May 12	4	June 1	4	June 16	4	July 1
1	May 13	5	June 2	6	June 17	9	July 2
3	May 15	4	June 3	9	June 18	2	July 3
2	May 16	1	June 4	16	June 19	4	July 4
2	May 21	1	June 5	9	June 20	4	July 5
5	May 22	6	June 6	4	June 21	3	July 6
1	May 23	9	June 7	8	June 22	2	July 7
7	May 24	10	June 8	7	June 23	2	July 8
2	May 25	12	June 9	4	June 24	2	July 9
1	May 26	2	June 10	3	June 25	3	July 10
6	May 27	7	June 11	7	June 26	4	July 11
5	May 28	3	June 12	6	June 27	3	July 12
1	May 29	3	June 13	6	June 28		

As is shown in Table I, the time of emerging of all moths varied from May 9 to July 12. The greatest number of moths to emerge on any one day was 16, and these individuals issued on June 19. There was no marked period when the vast majority of adults came forth, as is sometimes the case with certain species. A summary of Table I shows that 45 emerged from May 9 to 31, 78 from June 1 to 15, and 104 from June 16 to 30, making in all for June a total of 182; and 42 from July 1 to 12. Most of the moths issued during the month of June, and somewhat the greater number during the latter half of the month. In pecan orchards moths were not commonly seen until the early part of June, and by the middle of July they were rarely observed; but belated individuals were met until the last days of July.

Rearing cages to determine the emergence of moths during 1914 were examined daily, except on June 7, 14, 16, 21, 28, July 5, 12, 19, 26, and August 2. The dates of issuance of 385 individuals are shown in Table II.

TABLE II.—*Time of emergence of moths of the pecan leaf case-bearer during 1914 at Monticello, Fla*

Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.
	1914.		1914.		1914.		1914.
1	May 15	4	June 4	3	June 22	8	July 8
4	May 18	2	June 5	20	June 23	4	July 9
3	May 20	2	June 6	38	June 24	5	July 10
2	May 21	3	June 8	22	June 25	6	July 11
4	May 22	3	June 9	14	June 26	1	July 13
1	May 23	5	June 10	13	June 27	5	July 14
6	May 25	7	June 11	22	June 29	4	July 15
2	May 27	7	June 12	13	June 30	2	July 16
2	May 29	8	June 13	14	July 1	5	July 17
2	May 30	13	June 15	9	July 2	1	July 21
2	May 31	6	June 17	15	July 3	4	July 27
7	June 1	2	June 18	13	July 4	2	July 29
6	June 2	3	June 19	11	July 6	2	Aug. 4
4	June 3	7	June 20	5	July 7	2	Aug. 5

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As is shown in Table II, the first moths of the season issued on May 15 and the last adults appeared on August 5, making a period of 82 days for the emergence of all individuals. The maximum emergence for a single day occurred on June 24, when 38 moths issued. A summary of Table II shows that 29 moths emerged from May 15 to 31, 238 from June 1 to 30, 114 from July 1 to 31, and 4 from August 1 to 5. Out of 238 moths to issue in June, 71 came forth during the first half of the month, while 167 emerged during June 15 to 30, which marks the period of maximum emergence. It is to be noted also that of the 114 moths issuing during July 100 emerged from July 1 to 14. So far as the records go, the last moth observed in the field was on August 1. From July 20 to the close of the month there was an extremely sudden decrease in the number of adults in the various pecan orchards in which observations were made.

During the season of 1915 rearing cages to determine the emergence of moths were examined daily, except on June 13, 15, 17, July 6, 13, 15, and 22. The dates of issuance of 591 individuals are shown in Table III.

TABLE III.—*Time of emergence of moths of the pecan leaf case-bearer during 1915 at Monticello, Fla.*

Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.
	1915.		1915.		1915.		1915.
2	May 22	6	June 5	31	June 21	6	July 4
3	May 24	20	June 6	31	June 22	13	July 5
1	May 25	11	June 7	24	June 23	22	July 7
1	May 26	5	June 8	12	June 24	7	July 8
4	May 27	7	June 9	6	June 25	6	July 9
2	May 28	8	June 10	14	June 26	10	July 10
10	May 29	22	June 11	11	June 27	13	July 11
1	May 30	22	June 12	16	June 28	5	July 12
2	May 31	33	June 14	16	June 29	10	July 14
16	June 1	12	June 16	6	June 30	3	July 16
5	June 2	12	June 18	16	July 1	1	July 17
21	June 3	16	June 19	10	July 2	2	July 21
6	June 4	28	June 20	22	July 3	2	July 23

As shown in Table III, the first moth of the season issued on May 22, and the last adults appeared on July 23. A summary of Table III shows that 26 moths emerged from May 22 to 31, 417 from June 1 to 30, and 148 from July 1 to 23. Out of 417 adults issuing during June, 235 appeared from June 16 to 30, which period marks the time of maximum emergence. It should be noted also that of 148 moths emerging during July, 140 issued from July 1 to 14.

The habits of moths in pecan orchards.—When the moths are at rest the wings are folded rooflike on the abdomen and the head and anterior part of the body are held in a somewhat elevated position. During the day the moths prefer to frequent the weeds at the base of the trees, but they are also to be found hiding in the dense foliage of

the lower limbs. When disturbed they fly rather reluctantly from their places of concealment, but their flight is usually so rapid that it is quite difficult to follow them, although the distance traveled may be only a few feet. When alarmed, moths hiding in the débris around the base of trees often work their way into the dead leaves rather than take wing, and because of their protective color they are likely to escape detection.

Length of life of moths.—The average length of life for 26 adults was found to be 4.8 days, the maximum 10, and the minimum 2. Data bearing on the length of life are insufficient to give any generalization.

Oviposition and the length of egg stage.—It was very difficult to get reared specimens of moths to oviposit in confinement, but moths collected in pecan orchards laid eggs rather freely in some instances in rearing cages, upon both surfaces of the leaves. Under natural conditions moths oviposit only upon the underside of the leaflets. The greatest number of eggs recorded as having been deposited by a single individual was 182, which were laid by a moth collected in the field on July 20, 1916. The eggs were deposited as follows: 157 on July 21, 22 on July 22, and 3 on July 23. The records show that a period of from three to five days elapsed between the time of emergence of moths and the time of oviposition. Tables IV and V show the length of the egg stage.

TABLE IV.—*Length of egg stage of the pecan leaf case-bearer at Monticello, Fla.*

Date moths were placed in cage.	Date of oviposition.	Date of hatching.	Length of egg stage.
			Days.
June 15, 1913	June 17, 1913	June 24, 1913	7
Do	June 18, 1913	June 25, 1913	7
Do	June 19, 1913	do	6
Do	June 20, 1913	June 26, 1913	6
June 30, 1914	July 2, 1914	July 7, 1914	7
July 13, 1914	July 16, 1914	July 24, 1914	8
Maximum			8
Minimum			6

As shown in Table IV, the length of the egg stage was from 6 to 8 days. The moths used in obtaining these records were collected in the field, and from data on hand it is impossible to compute the average length of the egg stage. Upon emerging from the eggshell the larva feeds upon the leaf surface at the place where the egg is deposited.

TABLE V.—*Length of egg stage of the pecan leaf case-bearer at Monticello, Fla., in 1915.*

Number of eggs from which larvæ emerged.	Date of oviposition.	Date of hatching.	Length of egg stage.
	1915.	1915.	*Days.*
1	July 17	July 23	6
1	...do....	July 24	7
4	July 18	July 26	8
18	July 24	Aug. 1	8
1	...do....	Aug. 2	9
7	July 31	Aug. 6	6
60	...do....	Aug. 7	7
2	Aug. 4	Aug.11	7
23	Aug. 5	Aug.12	7
1	...do....	Aug.13	8
Maximum			9
Minimum			6
Average for 118 individuals			7.144

It will be noted from Table V that the average length of the egg stage for 118 individuals was 7.14 days, the maximum 9, and the minimum 6.

THE PUPA STAGE.

Of the larvæ under observation that transformed to pupæ during 1913, the first pupated on April 20, while during 1914 and 1915 the first pupæ did not appear until May 5. During the season of 1914 the actual time of earliest pupation was, perhaps, a trifle earlier than recorded, since in cages in which only the daily emergence of moths was observed the dates of pupation were not taken, and some moths from the cages issued as early as May 15. It is very likely that some larvæ in these cages transformed to pupæ during the last few days of April.

During the year 1913 the length of the pupa stage was determined for 66 individuals, as is shown in Table VI:

TABLE VI.—*Length of pupa stage of the pecan leaf case-bearer at Monticello, Fla., during 1913.*

Number of individuals.	Date of—		Days as pupa.	Number of individuals.	Date of—		Days as pupa.
	Pupation.	Emergence.			Pupation.	Emergence.	
	1913.	1913.			1913.	1913.	
1	Apr. 20	May 13	23	1	May 21	June 8	18
2	Apr. 25	May 15	20	2	...do....	June 9	19
1	...do....	May 16	21	3	...do....	June 11	21
1	May 2	May 21	19	1	...do....	June 12	22
2	...do....	May 22	20	1	...do....	June 13	23
1	May 4	May 24	20	2	May 22	June 11	20
2	May 6	...do....	18	2	...do....	June 12	21
2	May 8	May 28	20	1	...do....	June 13	22
1	May 9	May 27	18	1	May 23	June 15	23
1	...do....	May 31	22	2	May 27	June 17	21
1	May 11	May 30	19	2	May 29	June 19	21
1	...do....	June 1	21	1	May 30	June 20	21
4	May 12	June 2	21	3	May 31	...do....	20
1	May 13	...do....	20	1	June 1	June 21	20
3	May 14	June 3	20	1	...do....	June 23	22
1	...do....	June 5	22	2	June 2	...do....	21
1	May 15	June 3	19				
5	May 19	June 7	19				
2	...do....	June 8	20	Average			19.89
3	...do....	June 9	21	Maximum			23
3	May 20	June 6	17	Minimum			17
1	...do....	June 8	19				

As is shown in Table VI, the average length of the pupa stage during 1913 was 19.89 days, the maximum 23, and the minimum 17.

Table VII shows the length of the pupa stage for 45 individuals for the season of 1914.

TABLE VII.—*Length of pupa stage of the pecan leaf case-bearer at Monticello, Fla., during 1914.*

Number of individuals.	Date of—		Days as pupa.	Number of individuals.	Date of—		Days as pupa.
	Pupation.	Emergence.			Pupation.	Emergence.	
	1914.	1914.			1914.	1914.	
2	May 5	May 25	20	1	May 23	June 8	16
1	May 10	May 30	20	2	...do....	June 9	17
1	May 11	...do....	19	3	May 25	June 10	16
1	...do....	May 29	18	3	...do....	June 11	17
1	May 12	May 31	19	1	...do....	June 12	18
1	...do....	June 1	20	1	...do....	June 13	19
1	May 13	May 31	18	1	...do....	June 11	16
1	...do....	June 1	19	2	May 26	June 12	17
1	May 14	June 2	19	1	...do....	June 13	18
1	May 15	...do....	17	1	May 27	...do....	17
2	...do....	...do....	18	2	May 28	June 15	18
1	...do....	...do....	17	1	May 29	...do....	17
1	May 16	...do....	18	2	June 9	June 26	17
1	...do....	June 4	19				
2	May 18	...do....	17				
2	...do....	June 5	18	Average			17.66
2	...do....	June 6	19	Maximum			20.
1	May 19	June 8	20	Minimum			16.
1	May 22	June 10	19				

During 1914 the average length of the pupa stage was determined to be 17.66 days, the maximum being 20 and the minimum 16.

Table VIII shows the length of the pupa stage for 109 individuals for the season of 1915.

TABLE VIII.—*Length of the pupa stage of the pecan leaf case-bearer at Monticello, Fla., during 1915.*

Number of individuals.	Date of—		Days as pupa.	Number of individuals.	Date of—		Days as pupa.
	Pupation.	Emergence.			Pupation.	Emergence.	
	1915.	1915.			1915.	1915.	
3	May 5	May 22	17	1	May 25	June 11	17
3	...do....	May 23	18	1	...do....	June 12	18
1	May 6	May 22	16	2	May 28	June 16	19
1	...do....	May 23	17	1	May 29	...do....	18
2	...do....	May 24	18	1	May 31	...do....	16
4	May 7	...do....	17	1	...do....	June 18	18
3	...do....	May 25	18	5	June 1	...do....	17
1	May 8	...do....	17	3	June 2	...do....	16
1	May 9	...do....	16	12	...do....	June 19	17
1	...do....	May 27	18	3	...do....	June 20	18
1	May 13	May 30	17	4	June 3	June 19	16
1	May 19	June 5	17	8	...do....	June 20	17
5	May 20	June 6	17	7	...do....	June 21	18
2	...do....	June 7	18	1	June 13	July 1	18
2	May 21	...do....	17	2	June 14	June 30	16
1	...do....	June 8	18	2	...do....	July 1	17
1	May 22	June 9	18	2	...do....	July 3	19
2	May 23	June 8	16	5	June 16	...do....	17
2	...do....	June 9	17	1	June 17	...do....	16
1	...do....	June 10	18				
1	May 24	June 9	16				
5	...do....	June 10	17	Average			17.15
2	...do....	June 11	18	Maximum			19.
1	May 25	June 10	16	Minimum			16.

THE LARVA STAGE.

During the season of 1913 eggs were found to hatch from about the middle of May until the last days of July, and during the season of 1914 and 1915 from the latter part of May until the first few days of August. The period over which the eggs are hatching depends, of course, upon the time of emergence of moths, and it will be noted in Tables I, II, and III that there was some variation in the issuance dates of adults during 1913, 1914, and 1915. When the young larvæ gnaw their way out of the eggshells they commence feeding upon the portion of leaflet immediately adjacent to the place where oviposition occurred. Throughout the summer and during the early fall the larvæ feed very sparingly upon the foliage, and as they extend their feeding quarters they enlarge the little winding or spiral cases which afford them protection. Although the larvæ may feed for nearly three months or even longer in some instances, they hardly attain a length greater than six one-hundredths of an inch. During the latter part of September these larvæ begin to seek hibernating quarters around the buds, where they construct small, compactly woven, oval hibernacula, and by the middle of October practically all larvæ will have left the foliage and may be found snugly protected in the hibernacula. These little "worms" very wisely abandon the compound leaves upon which they have been feeding, just a short time before the foliage begins to drop in the autumn, in order to attach the winter cases securely to the buds and twigs.

The larvæ remain in hibernation until the latter part of March or the first days of April, at which time the buds on pecan trees usually begin to open. Just as the buds are opening, the larvæ emerge from their hibernacula and attack the unfolding leaves. The pernicious feeding habits of the larvæ at this time result in serious injury to the foliage and in greatly reducing the yield of nuts. During the year 1913 the larvæ reached full growth from about April 20 until the latter part of June, but the majority pupated between May 10 and June 10. During the seasons of 1914 and 1915 the majority of the larvæ were about a week to ten days later in reaching maturity.

NATURAL ENEMIES.

Three species of birds—the blue jay (*Cyanocitta cristata*), the mockingbird (*Mimus polyglottos*), and the orchard oriole (*Icterus spurius*)—have been observed feeding upon the larvæ of the pecan leaf casebearer. These birds, as well perhaps as those of other species, do much to check the ravages of this pest, and their protection in the pecan orchard should be encouraged. The blue jay very likely is more beneficial than harmful to the pecan grower. In the writer's opinion the good that this bird does in feeding upon injurious pecan

insects more than offsets the injury that it is accused of doing in the fall of the year, when it may take a few nuts from the pecan trees.

The writer has reared a number of parasitic insects from the larvæ and pupæ of this case-bearer, as follows: *Itoplectis conquisitor* Say, *Triclistus apicalis* Cress., *Calliephialtes grapholithae* (Cress.), and *Pristomerus* sp., belonging to the family Ichneumonidae; *Macrocentrus delicatus* Cress., *Meteorus* sp., *Habrobracon variabilis* Cush., and *Orgilus* sp., belonging to the family Braconidae; and *Secodella acrobasis* Cwfd., which has been described as a new species by Mr. J. C. Crawford (19), of the U. S. National Museum, and *Cerambycobius* sp., belonging to the superfamily Chalcidoidea. Two species of Tachinidae were reared from this case-bearer and were identified by Mr. W. R. Walton, of the Bureau of Entomology, as *Leskiomima tenera* Wied. and *Exorista* near *pyste* Walker. This last he considers as probably a new species. Gossard (12) reported rearing *Spilochalcis vittata* (Fab.) and *Itoplectis conquisitor* Say from this host. It is interesting to note that on one occasion specimens of *Trichogramma minutum* Riley were reared from the eggs of the pecan leaf case-bearer. Of the numerous parasites preying upon this pest, the most effective is the small chalcidoid, *Secodella acrobasis* Cwfd., which was reared in great abundance from the overwintering larvæ.

METHODS OF CONTROL.

DIPPING AND SPRAYING TESTS FOR THE DESTRUCTION OF LARVÆ IN HIBERNATION.

In order to determine the effect of various spray materials on the larvæ in their hibernacula, a series of tests was made. For this work small twigs that were badly infested were selected for the treatment, which consisted in immersing the twigs in the materials used. After the treatment had been effected the twigs were kept in separate glass jars. The results of this series of experiments are shown in Table IX.

TABLE IX.—*Dipping tests with sprays for destruction of hibernating larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1913.*

Experiment No.	Number of twigs treated.	Material used.	Date of application.	Per centage of larvæ emerging from hibernacula.
I	25	Miscible oil (1:12)	Feb. 11, 1913	18
II	25	Miscible oil (1:15)		15
III	25	Miscible oil (1:18)		20
IV	25	Miscible oil (1:20)		20
V	15	Miscible oil (undiluted)		2
VI	25	10 per cent kerosene emulsion		15
VII	25	20 per cent kerosene emulsion		15
VIII	25	Commercial lime-sulphur solution (1:8)		10
IX	25	40 per cent nicotine sulphate (1:32)		10
X	25	Check; untreated		50

For some reason, presumably because the twigs were kept in too dry a condition, many larvæ failed to emerge from hibernacula that were not treated, as is shown in Table IX. The best results were obtained with undiluted miscible oil, while strengths ranging from 1:12 to 1:20 gave considerably less benefit for the treatment, as was also the case when 10 and 20 per cent kerosene emulsions were employed. Commercial lime-sulphur solution at 1:8 and 40 per cent nicotine sulphate at 1:32 ranked second in effectiveness.

Further dipping tests were made with commercial lime-sulphur solution on March 26, 1914. The strengths employed were 1:8 and 1:10, in which thirty heavily infested pecan twigs were dipped, and after the treatment the twigs were caged immediately in jars and placed in the out-of-doors insectary. By March 31 many of the larvæ were emerging from their hibernacula and feeding upon the developing buds. Further observations showed that lime-sulphur at these strengths was not effective in preventing many larvæ from emerging from winter quarters.

Table X shows further dipping and spraying experiments with lime-sulphur and miscible oil.

TABLE X.—*Dipping and spraying experiments for destruction of hibernating larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1916.*

Experiment No.	Treatment.	Date of application.	Result.
I	Dipped twigs in commercial lime-sulphur solution (1:8), testing 32° Baumé.	Mar. 7, 1916	Many larvæ emerged and destroyed every bud.
II	Sprayed twigs with commercial lime-sulphur solution testing 32° Baumé.	....do.....	Many larvæ emerged and destroyed most of the buds.
III	Sprayed twigs with miscible oil at 1:15.	....do.....	Many larvæ emerged and destroyed practically every bud.
IV	Check; twigs untreated.....	.....	Larvæ emerged and readily destroyed every bud.

The twigs used in these experiments were kept in water or moist soil in order to insure the proper development of the buds. The first observations were made on April 17, 1916, and results as shown in Table X indicate the condition of the foliage. It will be noted that the lime-sulphur and miscible oil failed to destroy the larvæ.

SPRAYING EXPERIMENTS[1] FOR THE DESTRUCTION OF LARVÆ IN HIBERNATION.

A series of spraying experiments was conducted with several of the standard winter sprays to find out their effect upon larvæ in hibernation, and in all cases the material was applied thoroughly by means of a gasoline-power outfit.

[1] The spraying was done in bearing pecan orchards belonging to the Standard Pecan Co. and the Summit Nurseries, both of Monticello, Fla., and to Mr. Charles E. Pabst, of Ocean Spring, Miss.

The results of these experiments are as follows:

TABLE XI.—*Spraying experiments for the destruction of hibernating larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1913.*

Plat No.	Number of trees.	Treatment.	Date of application.	Results.
			1913	
I	11	Commercial lime-sulphur solution, testing 33° Baumé, at 1 gallon to 8 gallons of water.	Mar. 3	40 per cent of the larvæ emerged from hibernacula. Buds and foliage very seriously damaged by larvæ.
V	10	Miscible oil at 1 gallon to 20 gallons of water.	Mar. 25	75 per cent of the larvæ emerged from hibernacula. Buds were badly damaged by larvæ.
VII	14	Check; untreated.....	.....	Practically all larvæ emerged. Nearly every bud was either totally or partially destroyed. Some trees were completely defoliated.

Neither the lime-sulphur solution nor the miscible oil gave satisfactory results, but of the two, lime-sulphur was the better. In this series of experiments a proprietary insecticide consisting of distillate oil, tobacco, and soap, and another one consisting principally of oil were tried at dormant strengths in Plats II, III, and IV, which are not included in Table XI, and both of these were found to be ineffective against the hibernating larvæ.

On February 15, 1913, in the Pabst orchard at Ocean Springs, Miss., fifteen 10-year-old trees were sprayed with commercial lime-sulphur at 1 gallon to 8 gallons of water, and on the same date six 10-year-old trees were sprayed with miscible oil at the rate of 1 gallon to 15 gallons of water. Since it was impossible for the writer to make observations on these sprayed trees because of stress of work at Monticello, Fla., Mr. Chas. E. Pabst, of Ocean Springs, Miss., was requested to report the results of these experiments. In his report he stated that there seemed to be a slight benefit derived from the lime-sulphur treatment, but so far as could be determined the miscible-oil-sprayed trees were as badly infested with larvæ as the trees that were left untreated.

In order to obtain additional information on the two most common dormant season sprays, a series of spraying experiments was conducted at Ocean Springs, Miss., and another at Monticello, Fla. The results of this work are shown in Tables XII and XIII.

TABLE XII.—*Spraying experiments for the destruction of hibernating larvæ of the pecan leaf case-bearer at Ocean Springs, Miss., in 1914.*

Plat No.	Number of trees.	Treatment.	Date of application.	Result.
			1914	
I	32	Commercial lime-sulphur solution, testing 33° Baumé, at 1 gallon to 8 gallons of water.	Mar. 9	Very slightly benefited. Sufficient number of larvæ emerged to do considerable damage to buds and foliage.
II	17	Commercial lime-sulphur solution, testing 33° Baumé, at 1 gallon to 10 gallons of water.	...do.....	Very slight benefit. A large percentage of larvæ emerged from hibernacula and severely injured the buds and foliage.
III	10	Check; unsprayed.....	.....	Practically all larvæ that were not parasitized emerged from hibernacula. Buds and foliage were severely injured.

TABLE XIII.—*Spraying experiments for the destruction of hibernating larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1914.*

Plat No.	Number of trees.	Treatment.	Date of application.	Results.
I	12	Commercial lime-sulphur solution at 1 gallon to 8 gallons of water.	Mar. 22, 1914	Slight benefit, but a sufficient number of larvæ emerged to do much damage to buds and foliage.
II	10	Commercial lime-sulphur solution at 1 gallon to 10 gallons of water.	.....do.....	Slight benefit, but many larvæ emerged from hibernacula and did considerable damage to buds and foliage.
III	8	Miscible oil at 1 gallon to 20 gallons of water.	.....do.....	Practically no benefit derived from the treatment.

The results, as will be noted in Tables XII and XIII, show that the lime-sulphur solution at 1:8 and 1:10 gave a slight benefit, but that miscible oil was a decided failure. The number of larvæ destroyed by the lime-sulphur treatments was not sufficient to combat this pest satisfactorily. Although it has been suggested and advised by certain entomological writers that this pest can be controlled by the use of lime-sulphur during the dormant season, the results of all the experiments show conclusively that the treatment can not be depended upon as a remedy for the pecan leaf case-bearer.

SPRAYING EXPERIMENTS AGAINST OVERWINTERED LARVÆ.

EXPERIMENTS AT MONTICELLO, FLA.

The work at Monticello, Fla., was conducted in the pecan orchards of the Summit Nurseries and the Standard Pecan Co. For the spraying regular orchard gasoline-power outfits were used and the spray material was applied very thoroughly at a pressure ranging from 175 to 200 pounds. The results of the experiments are shown in Tables XIV and XV.

TABLE XIV.—*Spraying experiments against the larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1913.*

Plat No.	Number of trees.	Treatment.	Date of application.	Results.
VI	55	Paste lead arsenate at 3 pounds plus Bordeaux mixture 4–5–50.[1]	Apr. 18, 1913	Not controlled satisfactorily. About 50 per cent of the larvæ were destroyed, but the buds were badly injured.
VII	14	Check; unsprayed.....	.....	Most buds were infested by larvæ. Some trees were nearly defoliated.

[1] Bordeaux mixture was used for fungicidal purposes.

TABLE XV.—*Spraying experiments against the overwintering larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1914.*

Plat No.	Number of trees.	Treatment.	Date of application.	Results.
IV	10	Commercial lime-sulphur solution at 1 gallon to 40 gallons of water.	Apr. 2, 1914	Not controlled. Some few larvæ killed, but the majority continued to feed upon the buds and foliage.
V	10	40 per cent nicotine sulphate at 1 part to 700 parts of water.	.....do.....	Not controlled. Much damage done to the buds and foliage.
VI	25	Paste lead arsenate at 3 pounds to 50 gallons of water (2 applications).	Apr. 2 and 10, 1914.	Not satisfactorily controlled. Many larvæ killed, but sufficient numbers escaped to inflict serious injury to buds and foliage.

As shown in Table XIV, a single application of paste arsenate of lead at 3 pounds to 50 gallons of Bordeaux mixture, made on April 18, 1913, failed to control the pest, although there was considerable benefit in favor of the sprayed over the check trees. Table XV shows that on trees treated with commercial lime-sulphur solution at 1:40 and 40 per cent nicotine sulphate at 1:700 on April 2, 1914, at which time the larvæ were emerging from their hibernacula, little or no benefit was derived from the treatment. Compared with the checks, the trees in Plat VI, which received two heavy applications of paste lead arsenate at 3:50 on April 2 and 10, showed that there was much in favor of the treatment, but sufficient numbers of the larvæ escaped the poison to do serious damage to the buds and foliage.

On account of the manner in which the larvæ feed upon the buds, it was found to be difficult to kill a large proportion of them before considerable damage had been done to the foliage. Results show that spraying with lead arsenate during the spring can not be relied upon as an effective remedy for this pest.

SPRAYING EXPERIMENTS AGAINST LARVAE IN THE SUMMER.

EXPERIMENTS AT MONTICELLO, FLA.

After discovering the manner in which the larvæ attack the foliage during the summer, spraying experiments were conducted to find out if the case-bearer could not be controlled practically at this stage of its life cycle. The results of this line of work are embodied in the following tables. Table XVI shows the effect of the treatment of 113 ten-year-old pecan trees in the orchard of the Summit Nurseries.

TABLE XVI.—*Spraying experiments against the larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1913.*

Plat No.	Number of trees.	Treatment.	Date of application.	Results.
I	113	One application of paste lead arsenate at 3 pounds to 50 gallons of water.	Aug. 14 and 15, 1913.	Very satisfactory control. Nearly all larvæ were killed and only a very few remained to construct hibernacula in the autumn. Was exceedingly difficult to detect any hibernacula. No appreciable amount of damage was done by the few overwintering larvæ to the buds during the spring.
II	12	Check; untreated.....	.....	As many as 12 hibernacula were found around a single bud; the average was about 3 hibernacula to the bud. During the spring the larvæ appeared in numbers and seriously damaged the buds and foliage. Some trees were nearly defoliated.

The results obtained on Plat I, as shown in Table XVI, were highly satisfactory, since most of the larvæ were killed by the arsenical application. By destroying the larvæ during the late summer or early autumn, the trees were protected from attacks during the subsequent spring, at which time very serious injuries occur to the buds and tender foliage through the peculiar manner of the feeding of overwintering larvæ. During the following spring (1914), the trees on Plat I put forth their foliage in perfect condition, but on account of the ravages of the case-bearer larvæ the unsprayed trees (Plat II) were kept in a state of partial or total defoliation for several weeks, and this condition interfered seriously with the setting of nuts. A slight arsenical injury was done to the foliage, but in no case was the damage so severe as to cause the leaves to drop.

More extensive spraying experiments were carried out with lead arsenate in 1914 than in 1913. Table XVII shows the series of experiments conducted in the Abe Simon orchard.

TABLE XVII.—*Spraying experiments against the larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1914.*

Plat No.	Number of trees.	Treatment.	Date of application.	Result.
			1914	
I	22	Powdered lead arsenate at 2 pounds to 50 gallons of water.	Aug. 13.....	Practically perfect control. Scarcely any larvæ succeeded in escaping the poison to construct hibernacula. Foliage rather seriously injured by the heavy application of arsenical.
II	4	Check; unsprayed.....	.....	Trees were badly infested, as was determined by the great abundance of hibernacula and the prevalence of larvæ in the buds during the following spring.
III	18	Paste lead arsenate at 3 pounds to 50 gallons of water.	Aug. 14.....	Practically perfect control. Scarcely any larvæ succeeded in escaping the poison to construct hibernacula. Foliage rather seriously injured by the heavy application of arsenical.

On Plats I and III the case-bearer was satisfactorily controlled, while on Plat II, which was left untreated, very serious damage was done during the spring by the overwintering larvæ. Rather serious injury was done to the foliage on Plats I and III, owing in part to the showery weather that followed the spraying, which made conditions favorable for the suspension of free arsenic on the leaves. The sprayed trees shed their foliage a little sooner than the checks, but defoliation did not take place so early as to cause the trees to bud out again.

A series of dosage tests with lead arsenate was carried out for the purpose of determining the proper strength necessary to control effectively the pest under orchard conditions. The results of this work are contained in Table XVIII.

TABLE XVIII.—*Spraying experiments against the larvæ of the pecan leaf case-bearer to determine the most effective dosage of lead arsenate: Monticello, Fla., 1914.*

Plat No.	Number of trees.	Treatment.	Date of application.	Results.	
				Degree of infestation.	Arsenical injury to foliage.
			1914		
I	26	Powdered lead arsenate at 1½ pounds to 50 gallons of water.	Aug. 20	Practically none.	Serious.
II	16	Powdered lead arsenate at 1 pound to 50 gallons of water.	...do.....	.....do.....	Rather serious.
III	31	Powdered lead arsenate at ½ pound to 50 gallon of water.	...do.....	Light infestation	Slight burning.
IV	6	Check; unsprayed.....	...do.....	Very heavy infestation.	
V	37	Paste lead arsenate at 1 pound to 50 gallons of water.	...do.....	Light infestation	Slight burning.
VI	24	Paste lead arsenate at 1½ pounds to 50 gallons of water.	Aug. 22	Very light infestation.	Somewhat pronounced.
VII	21	Paste lead arsenate at 2 pounds to 50 gallons of water.	...do.....	Practically none.	Rather serious.
VIII	18	Paste lead arsenate at 2½ pounds to 50 gallons of water.	...do.....	.....do.....	Serious.
IX	26	Paste lead arsenate at 3 pounds to 50 gallons of water.	...do.....	.....do.....	Do.
X	24	Two pounds of paste arsenate of lead plus 4 pounds of lime to 50 gallons of water.	...do.....	.....do.....	Only a trace of burning.

As is shown in Table XVIII, the powdered lead arsenate at ½ pound (Plat III), and paste form at 1 pound (Plat V), as well as 1½ pounds (Plat VI), to 50 gallons of water were found to be too weak for effective work, while the powdered lead arsenate at 1 pound and 1½ pounds and the paste form at 2, 2½, and 3 pounds gave very satisfactory control. It was discovered that pecan foliage was quite susceptible to arsenical injury, for on all plats there was some burning. The worst burning occurred on Plats I, VIII, and IX, where the stronger dosages of lead arsenate were used; but where the weaker dosages were employed the injury was considerably lessened. The foliage on Plat X, sprayed with lead arsenate to which lime was added, was in the best condition, as only a trace of burning occurred.

Spraying experiments were conducted during the summer of 1915 for the purpose of determining the effects of various forms of lead arsenate on pecan foliage. The pecan trees selected were 12 years old and of a good size for their age. The spray material was very thoroughly applied by means of a gasoline-power outfit, using a pressure of about 200 pounds. Table XIX shows the results of this work.

TABLE XIX.—*Spraying experiments against the larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1915.*

Plat No.	Number trees.	Treatment.	Date of application.	Results.	
				Degree of infestation.	Extent of arsenical injury to foliage.
			1915.		
I	18	Powdered lead arsenate 1½ pounds, plus 3 pounds of lime to 50 gallons of water.	Aug. 24	Practically none.	Foliage in good condition; no appreciable burning.
II	18	Powdered lead arsenate 1 pound, plus 3 pounds of lime to 50 gallons of water.	...do.....	.....do.....	Do.
III	12	Paste lead arsenate 3 pounds, plus 3 pounds of lime to 50 gallons of water.	Aug. 25	.....do.....	Burning of foliage was rather serious.
IV	12	Paste lead arsenate 2 pounds, plus 3 pounds of lime to 50 gallons of water.	...do.....	.....do.....	Margin of leaves rather severely burned; but the trees did not shed their leaves prematurely.
V	5	Paste triplumbic lead arsenate 2 pounds, to 50 gallons of water.	...do.....	.....do.....	Foliage rather seriously burned, especially margin of leaves.
VI	7	Paste triplumbic lead arsenate 2 pounds, plus 3 pounds of lime to 50 gallons of water.	...do.....	.....do.....	Foliage in good condition; no appreciable burning.

As shown in Table I, the pecan leaf case-bearer was controlled satisfactorily on all plats, but only on Plats I, II, and VI was the spraying accomplished without appreciable arsenical injury to the foliage. Maximum burning of foliage occurred on Plat V, where triplumbic arsenate of lead paste alone was used; but even in this case the injury was not severe enough to cause premature defoliation. Plats III and IV, which received 3 pounds and 2 pounds, respectively, of paste arsenate of lead plus 3 pounds of lime to each 50 gallons of water, showed rather serious arsenical injury to the margins of the leaves, while Plats I and II, which received 1½ pounds and 1 pound, respectively, of the powdered form of arsenate of lead plus 3 pounds of lime to 50 gallons of water, showed no appreciable injury to the foliage. From these observations the powdered form of lead arsenate appears less likely to cause injury to the foliage than does the paste form.

Under no circumstances was it found safe to use effective dosages of lead arsenate (triplumbic or diplumbic) in either the paste or powdered form on pecan foliage without the addition of 3 or 4 pounds of stone lime per 50 gallons of water. The work with arsenicals indi-

cates that the pecan is practically as susceptible to burning as is the peach and that the same precautions must be used in order to prevent serious injury to its foliage.

FUMIGATION EXPERIMENTS AGAINST HIBERNATING LARVÆ.

Experiments Against Larvæ on Pecan Nursery Trees.

As the pecan leaf case-bearer may be freely distributed through the medium of nursery stock as larvæ in hibernacula about the buds, it was considered advisable to obtain some data in regard to fumigation. A specially constructed box, measuring 10 feet long, 3⅓ feet high, and 3 feet wide, was used for this work. The box was so made as to be practically air-tight. In order to test the effect of fumigation on the larvæ as well as on the plant itself, a number of infested, grafted, or budded pecan trees, ranging from 3 to 5 feet in height, were used. In order to have the trees in the best possible condition, they were dug from the nursery during the afternoon of the day before fumigation, and immediately after the fumigation experiments were completed the trees were set out in the laboratory yard at Monticello, Fla. The method and results of these experiments are shown in Table XX.

Table XX.—*Fumigation experiments on pecan nursery trees for destruction of overwintering larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1916.*

Experiment No.	Number of trees.	Treatment.	Date of fumigation.	Results.
			1916.	
I	8	Fumigated for 1 hour with 1 ounce of sodium cyanid [1] per 100 cubic feet, using formula 1–2–3.[2]	Feb. 25	Larvæ were not killed, and these larvæ destroyed the buds. Trees were not injured by fumigation.
II	8	Fumigated for 1 hour with 1½ ounces of sodium cyanid per 100 cubic feet, using formula 1–2–3.	...do....	All larvæ were killed. No apparent injury to trees by fumigation.
III	8	Check; untreated.....	.....	Larvæ emerged in numbers and buds on the trees were badly damaged.

[1] Sodium cyanid used was equivalent to 129 per cent potassium cyanid.
[2] Formula: 1 ounce (avoirdupois) sodium cyanid, 2 fluid ounces of sulphuric acid, 3 fluid ounces of water to 100 cubic feet of space.

It will be noted in Table XX that in experiment I, where 1 ounce of sodium cyanid per 100 cubic feet was used, the case-bearer larvæ were not killed, while in experiment II, where 1½ ounces of cyanid was used, the results were very satisfactory, as no larvæ emerged from the hibernacula. On May 1, 1916, it was found that the buds on trees in experiments I and III were badly damaged by the larvæ and that the buds and foliage on trees in experiment II were not injured. So far as could be determined, the fumigation had no effect whatever on the trees, as both the check and fumigated

trees made practically the same amount of growth during the course of the season.

Further fumigation experiments were conducted during March, 1916, and are reported in Table XXI. Only badly infested pecan twigs were used in these experiments, and after being fumigated, they were placed in water bottles in order to insure proper development of the buds.

TABLE XXI—*Fumigation experiments on larvæ of the pecan leaf case-bearer at Monticello, Fla., in 1916.*

Experiment No.	Number of twigs.	Treatment.	Date of fumigation.	Results.	Remarks.
			1916.		
I	12	Fumigated for 1 hour with ½ ounce of sodium cyanid [1] per 100 cubic feet.	Mar. 4	Larvæ emerged from hibernacula.	All buds destroyed by larvæ.
II	12	Fumigated for 1 hour with ¾ ounce of sodium cyanid [1] per 100 cubic feet.	Mar. 3	....do.....	Nearly all buds were destroyed by larvæ.
III	12	Fumigated for 1 hour with 1 ounce of sodium cyanid [1] per 100 cubic feet.	...do....	A number of larvæ emerged from hibernacula.	Some buds were damaged by larvæ.
IV	12	Fumigated for 1 hour with 1 ounce of sodium cyanid [2] per 100 cubic feet.	...do....	.....do.....	A good many buds destroyed by larvæ.
V	12	Fumigated for 1 hour with 1½ ounces of sodium cyanid [1] per 100 cubic feet.	...do....	No larvæ emerged from hibernacula.	Buds did not unfold well.
VI	12	Check; not fumigated.....	...do....	Larvæ emerged from hibernacula.	All buds were destroyed by larvæ.
VII	15	Fumigated for 1 hour with 1½ ounces of sodium cyanid [1] per 100 cubic feet.	Mar. 29	No larvæ emerged from hibernacula.	No injury to buds from fumigation.
VIII	15	Fumigated for 1 hour with 2 ounces of sodium cyanid [1] per 100 cubic feet.	...do....	.....do.....	No injury to buds from fumigation.
IX	15	Check; not fumigated.....	...do....	Larvæ emerged from hibernacula.	All buds destroyed by larvæ.

[1] Used formula 1–2–3. [2] Used formula 1–1–3.

It will be noted in Table XXI that strengths of sodium cyanid of ½, ¾, and 1 ounce per 100 cubic feet failed to destroy the larvæ after one hour of exposure, while strengths of 1½ and 2 ounces per 100 cubic feet killed all larvæ. It is to be regretted that in these experiments a strength of 1¼ ounces was not used, as it was found that while 1 ounce was not enough, 1½ ounces destroyed larvæ while in the winter cases. Although the maximum strength used (1½ ounces per 100 cubic feet of space) is considerably in excess of that commonly employed in the fumigation of ordinary nursery stock, these experiments indicated that, while in a dormant condition, the pecan was perfectly capable of enduring the greater strength without injury.

In fumigation for the pecan leaf case-bearer materials should be used according to the following formula: 1–1½–2. This means that 1 ounce (avoirdupois) of sodium cyanid, 1½ fluid ounces of

sulphuric acid, and 2 fluid ounces of water should be used to each 100 cubic feet of space inclosed. In purchasing sodium cyanid it is essential to obtain a high-grade product, 96 to 98 per cent pure, or, in other words, one that contains not less than 51 per cent of cyanogen. Commercial sulphuric acid, specific gravity 1.84 (66° Baumé), which is approximately 93 per cent pure, should be used for fumigation in order to obtain the best results.

SUMMARY.

Although the pecan leaf case-bearer is preyed upon by a number of parasitic insects and several species of birds, it was found during a course of studies extending over a period of three years that neither the parasites nor any other natural checks could be relied upon to control it, but that certain artificial measures were successful.

It was found impossible successfully to control the pecan leaf case-bearer during the dormant season, at which time the larvæ were in hibernacula around the buds. Of the various spray materials tried for the destruction of hibernating larvæ, commercial lime-sulphur solution at the strength of 1 : 8 and 1 : 10 gave the best results, but this method failed to destroy a sufficient number of the larvæ to justify its use. Tests with miscible oils at 1 : 12, 1 : 15, 1 : 18, and 1 : 20, and 10 and 20 per cent kerosene emulsions applied during the dormant season were found to be ineffective.

Because of the manner in which the larvæ feed upon the buds and foliage, the pecan leaf case-bearer in the active larva stage during the spring was not satisfactorily controlled. Spraying experiments, using a single application of arsenate of lead (paste) at 3 pounds to 50 gallons of water, 40 per cent nicotine sulphate at 1 : 700, and commercial lime-sulphur solution at 1 : 40, were tried on orchard pecan trees as the larvæ emerged from their hibernacula, at which time the buds were beginning to unfold, but none of these materials proved effective. Two applications of arsenate of lead (paste) at 3 pounds to 50 gallons of water were made on large pecan trees, the first as the larvæ emerged from their winter cases and the second eight days later. This treatment destroyed many larvæ but was not entirely effective.

Experiments in spraying with certain strengths of lead arsenate, conducted during the summer (August), gave very satisfactory results in the control of this pest, as it was discovered that the young larvæ might be destroyed readily at this stage. Based on a large series of dosage tests with lead arsenate, conducted on orchard pecan trees, it was found that no strength weaker than 1 pound of the powdered form or 2 pounds of the paste to 50 gallons of water

could be relied upon to control the case-bearer. Paste lead arsenate at 1 pound and 1½ pounds or the powdered form at ½ pound to 50 gallons of water did not give satisfactory results, but the case-bearer was controlled equally as well with 1 pound of the powder or 2 pounds of paste as with 1½ pounds of the powder or 2½ or 3 pounds of the paste to each 50 gallons of water.

In conducting extensive spraying experiments it was soon discovered that pecan foliage is more or less susceptible to arsenical burning. Experience showed that it was unsafe to spray pecan trees with lead arsenate without adding at least 3 pounds of stone lime to each 50 gallons of water.

Fumigation experiments on the hibernating larvæ on pecan twigs and pecan nursery trees demonstrated that the larvæ could be destroyed by fumigating for one hour with 1½ ounces of sodium cyanid per 100 cubic feet of space inclosed.

RECOMMENDATIONS FOR CONTROL.

Experimental work extending over a period of more than three years has shown conclusively that no matter how badly an orchard may be infested, the pecan leaf case-bearer can be controlled successfully by a single application of an arsenical solution combined with lime, if made during the latter part of summer. Experiments have shown that the best results are obtained by using 1 pound of the powdered, or 2 pounds of the paste arsenate of lead and 3 pounds of freshly slaked lime to each 50 gallons of water. Under no circumstances should arsenate of lead be used without the addition of lime, as more or less injury to the foliage and nuts is likely to follow. It is evident that spraying may be done with equal effectiveness at any time between the first of August and the middle of September. Spraying earlier than August 1 is not to be relied upon as being fully effective, since all of the eggs will not have hatched by this time, and during the course of the spraying it is considered advantageous to the work to have all larvæ feeding upon the foliage. There is also some danger in delaying the spraying in the fall, as observations have shown that some larvæ seek hibernation quarters toward the latter part of September, although the majority of them do not construct winter cases until the first week or so in October. It should be borne in mind that only the larvæ which feed on poisoned foliage are killed, and those escaping pass the winter in hibernacula around the buds and come forth in the spring to feed upon the buds and young leaves. Therefore, all who would combat successfully the pecan leaf case-bearer must realize the importance of thorough and timely spraying.

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